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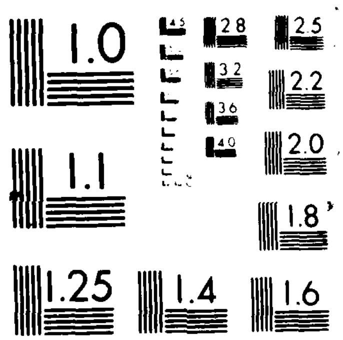
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IMPROVING PERFORMANCE OF THE NAVY INTERMEDIATE MAINTENANCE SYSTEM IN SAN DIEGO

Bela Feher
James A. Riedel
Arthur J. Farkas
Michael A. White
Warren J. Millard
Mark F. Levine

Approved by
Richard C. Sorenson

Released by
B. E. Bacon
Captain, U.S. Navy
Commanding Officer

and

James S. McMichael
Technical Director

Navy Personnel Research and Development Center
San Diego, California 92152-6800

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Navy repair activities are facing an increased workload at a time when the work force is being reduced. The demand for intermediate ship repairs is also increasing as periods between overhauls are extended. In response to this problem, researchers at the Navy Personnel Research and Development Center analyzed the operation of the intermediate maintenance system at San Diego to determine how productivity could be enhanced within these new requirements and constraints. Researchers used a sociotechnical systems design method to analyze the present system functioning, identify problems and causal factors, generate and choose alternative system designs, and evaluate them on site. The revised design was effective in improving the quality of information input to the repair system and in reducing the number of rejected work requests as well as the time required for planning. The design changes also reduced the time needed to screen work requests, to assign them to repair activities, and to make firm decisions regarding work acceptance. The sociotechnical systems design method is a valuable tool for productivity improvement in this and other military settings.

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FOREWORD

In October 1985, the Commander, Naval Surface Force, Pacific (COMNAVSURFPAC) requested that the Navy Personnel Research and Development Center (NAVPERSRANDCEN) provide technical analyses, recommendations, and assistance in implementing changes in the San Diego intermediate maintenance system to improve its functioning. A proposal to fund the work was accepted by the Navy Science Assistance Program. Support for the effort was also provided by the Naval Sea Systems Command, IMA Support Division, and the Shore Intermediate Maintenance Activity, San Diego.

A system analysis was performed and recommendations for system redesign were provided to COMNAVSURFPAC. This work is described in HFOSL Technical Note 72-86-4. Approval was given for further development and pilot testing of the recommendations. Upon completion of pilot testing, COMNAVSURFPAC authorized full operationalization of the recommendations by his staff and subordinate commands. During this process, NAVPERSRANDCEN also developed a draft instruction for the preparation of the Ship's Maintenance Action Form (NPRDC Technical Note 87-3), a form that supplies critical information to the repair activity.

Appreciation is expressed to CAPT James McIndoe, Commanding Officer of the Readiness Support Group, San Diego, for his cooperation and support.

B. E. BACON
Captain, U.S. Navy
Commanding Officer

JAMES S. McMICHAEL
Technical Director

SUMMARY

Navy repair activities are facing an increased workload at a time when the workforce is being reduced. The demand for intermediate ship repairs is also increasing as periods between overhauls are extended. (Intermediate repairs are defined roughly as more complex and extensive than those handled by the ship itself, but less so than those performed by shipyards.) In response to these new requirements and constraints, researchers at the Navy Personnel Research and Development Center (NAVPERSRANDCEN) analyzed the operation of the intermediate maintenance (IM) system at San Diego to determine how productivity could be enhanced.

THE CASE

Analysis and Redesign Process

NAVPERSRANDCEN researchers worked in collaboration with IM system personnel using the sociotechnical systems design method to analyze present IM system functioning, identify problems and causal factors, generate and choose alternative system designs, and evaluate them on site. The San Diego IM system includes the Readiness Support Group (RSG), which coordinates the IM function and brokers the work, and the Shore Intermediate Maintenance Activity (SIMA), along with a varying number of afloat IMAs (tenders).

Data used in the analyses were obtained through (1) interviews of customers of the IM system and key personnel within it; (2) observations of key events and processes; and (3) review of instructions, policy directives, and records. These data were used to develop a model of the way the system was currently functioning so that problem areas could be identified.

Three key problems were identified: (1) information inputs from customers to the repair system were of poor quality in terms of accuracy, validity, and completeness; (2) work acceptance decisions were neither timely nor binding, and (3) the planning process required excessive time and resources. These problems were interrelated, because the poor quality of the information inputs required the planners in the repair system to expend much time and effort checking, correcting, and completing work request information. This extended the decision-making process for work acceptance, delayed advance ordering of materials, and thereby reduced the system's capability to accomplish the repairs during the ship's availability.

Recommendations were presented by NAVPERSRANDCEN to the Commander, Naval Surface Forces, Pacific (COMNAVSURFPAC) to resolve these problems. The recommendation central to all others concerned the establishment of a maintenance representative (MR) position. The MR, a SIMA employee, would visit each ship at the time of submission of its work package to give immediate response to each work request in terms of adequacy of the information and capability of the repair activity to do the work. COMNAVSURFPAC sanctioned the testing of this and other recommendations on several pilot ships.

The recommendations were tested at SIMA using three test ships and two comparison ships. Refinements were developed as issues and problems were recognized. For example, instead of a single MR, a team of planning experts representing key areas (machinery, electrical, services, and hull) was sent to the ships. This team was organized and supervised by an assistant repair officer from SIMA, San Diego, and headed by the appropriate type desk officer from the RSG. Another test explored the transferability of the MR team concept to tenders.

Test Results

Overall data from three SIMA test trials showed that the quality of information input to the repair system had notably improved for the test ships relative to that for the comparison ships. Time required for planning was reduced by 27 percent, from an average of 6.7 days to 4.9 days for each work request. Work requests requiring ship checks (site visits) during planning were reduced from 37 percent to 3 percent. The trial aboard the tender was successful, although it was apparent that manning constraints could interfere with the tender's ability to assign Planning Department personnel to the MR teams during a ship visit.

DISCUSSION

The STS design method provided a systematic and comprehensive way to analyze system functioning for the development of design alternatives, and to test and refine them. It helped to determine that low quality of critical information concerning needed repairs was having a widespread negative effect, undermining the repair system's level of productivity, the fleet's degree of satisfaction with the repair process, and, most seriously, the fleet's state of readiness.

Although the system managers were inclined to view this problem as beyond their control, the STS design approach provided the means for developing an alternative organizational structure and procedures to address that problem. The new system design modified the sequential decision making by various parties by bringing personnel from customer ships and from the IM system together to review work requests early in the process. Working together, these parties could pool their knowledge and produce more accurate and complete information and better screening, brokering, and work acceptance decisions. In essence, these changes enabled the IM system to gain control over the quality of information it was receiving from the ships and improve its own efficiency in subsequent processing of the information.

Initial concern over the source and level of expertise required to staff the MR team was alleviated by drawing from the pool of experts available in the SIMA Planning Department and Repair Office. This was an efficient reallocation of resources, since a modest investment of their time at the initial stage in the repair process paid rich dividends in efficiency later. Team size remained fluid in order to adapt to the type of ship and the size of its work package. By including RSG in the team makeup, the established authority relationships between RSG and the repair activities were maintained. Based on these results, the MR team concept is being implemented throughout the San Diego IM system.

A further efficiency might result from separation of jobs by the MR team according to the planning expertise required. In a large number of cases where the job is routine, several days of lead time could be "saved" by direct delivery of the work requests by the MR team to the shop for handling by shop planners. Central planners could continue to process controlled work (work requiring many special quality assurance steps) and highly complex jobs.

Additional changes can be made in the organizational structure to further improve efficiency. Because all key parties from the ship, RSG, and SIMA are now simultaneously using the best possible technical, scheduling, and workload information while considering repair decisions, the elaborate staff structures created to deal with the poor quality of information can be eliminated. Reductions in overhead are possible within RSG and SIMA as duplicative screening, work acceptance, and planning activities are eliminated.

With improved efficiency in processing the work package, it is possible for ships to submit their work packages closer to the beginning of their availability period without compromising the lead time required by the IM system to order parts. This would allow more

accurate determination of the ship's maintenance requirements, reducing emergent work, and, thus, disruptions to the production process.

This case demonstrates the power of the STS design method to pinpoint causes of problems within complex systems such as military organizations. It guided the analysis group in generating and refining more effective system designs, and in installing, evaluating, and institutionalizing them. The method offers a powerful way to deal with structural relationships and procedures across system levels. Another measure of its strength is the synergistic relationship that develops from bringing client and consultant expertise together.

CONCLUSIONS AND RECOMMENDATIONS

1. System-wide implementation of MR teams in the San Diego IM system began a process of performance enhancement that should be continued. Some staff personnel at SIMA and RSG should be reassigned to production functions, including the newly created shop planner positions. The Planning Department should provide ongoing training of shop planners, who should carry the bulk of the planning load. Also, the timing of the ship's call-down should be reexamined with the goal of shortening the advance period to the minimum workable.

2. The STS design method is an effective tool for organization analysis within military settings because it can highlight root causes of system performance problems. It is useful too for developing and implementing new organizational structures and procedures that improve overall mission performance. Alternatively, the STS analysis can be used as the basis for selecting an appropriate change technology to meet a particular need of an organization, such as gain-sharing or training system design. Because these solutions address the causes of fundamental problems, improvements in mission performance should endure. Therefore, the STS design approach should be a method of choice where system-wide productivity improvements are sought.

3. Through its emphasis on control of key variances (unplanned deviations) in system production, the STS design method aids system managers in judicious investment of their limited resources. The method also helps managers target areas for redesign by identifying problems that have widespread effect on outcomes. This is an efficient way to raise overall system performance.

4. The comprehensive and systematic nature of the STS design approach provides a way to deal with the structural and operational interdependencies within complex, multilevel systems. This method should be used to analyze and redesign organizations where complex interrelationships are involved in determining system performance.

5. While the method is generalizable to a wide variety of organizations, the outcomes should be tailored to the needs and circumstances of specific systems. Organizations should use the method to develop their own unique redesigns, rather than to transfer solutions developed for other organizational situations.

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INTRODUCTION

This research is aimed at (1) improving the productivity and mission effectiveness of the intermediate maintenance (IM) system in San Diego, and (2) testing and extending a systematic and comprehensive method for organizational analysis and change applicable to production-oriented military settings. This report presents a case study of how the sociotechnical system (STS) design method was used to analyze and improve the structure and procedures for delivering IM to the fleet in the San Diego area. The discussion includes insights into applying the method in military settings as well as recommendations for continued development and change of the IM system to improve efficiency.

Those involved in intermediate-level repair activities are facing an increasing workload with fewer people than they have had in the past. This increase in work is caused by several factors, including policy changes with regard to operational and maintenance cycles and personnel allocations. Some work traditionally performed at shipyards (depot level) is being sent to intermediate maintenance activities (IMAs). In addition, ship maintenance schedules are now requiring more frequent intermediate-level maintenance to support extended overhaul intervals.

At the same time, the number of personnel assigned to IMAs is expected to either remain the same or be reduced. This workforce must also be distributed over a growing number of IMAs. These factors exacerbate the problem of an increasing workload, suggesting a need to focus on productivity improvement.

A related command concern has been the efficiency of the IM system (e.g., personnel overhead ratios). The efficiency issue suggests a need to critically assess administrative and support functions as well as production processes in determining overall mission effectiveness and improving it.

The need to improve productivity in the Navy IM community is but one instance of the need to create enduring improvement in mission performance of Navy organizations. Effectiveness in achieving these results requires comprehensive and systematic methods for organizational analysis, organization redesign, and change. Such methods must consider the interrelated and systemic nature of complex organizational systems (Feher & Levine, 1985b; Trist, Higgin, Murray, & Pollack, 1963). Traditional approaches to improving productivity lack this capability; we need, therefore, to supplement them. Traditional approaches to improving productivity include, for example, industrial engineering approaches (e.g., work measurement and work methods design), behavioral science approaches (e.g., financial incentives, performance appraisal, and goal setting), and technological approaches (e.g., new tools and techniques). While each of these approaches to productivity improvement has merit, results often fall short of expectations because none is either systematic or comprehensive.

They are not systematic because they do not acknowledge the interrelatedness of the various subsystems in a complex organization. For example, using incentives to increase motivation may be fruitless if work is not structured optimally or the technology to perform the task does not give workers control over factors critical to their performance. In the case of new technology, usually full realization of potential benefits can only occur if the structure and operation of related subsystems are redesigned in congruence with the new technological capabilities.

Traditional approaches to productivity improvement are not comprehensive in the sense that they focus on only a particular aspect or level of organizational functioning, while ignoring others. Industrial engineers may design work methods and develop a work measurement system

for a particular task or set of tasks and thereby increase an organization's potential productive capacity. By ignoring the larger system design, however, they may overlook system impediments that make it impossible for the organization to realize this new capacity.

The STS design method is an approach that promises to meet these needs. While this approach has been successfully used in the private sector, military organizations have unique features (such as high turnover rates of workers, supervisors, and managers, affecting incumbent knowledge and skill) that must be considered in applying such a change technology. The STS design method can lead to a better understanding of how features of the military setting affect the change process and how to sustain and transfer to other organizations those changes that successfully improve mission performance. Specifically, the STS design approach provides systematic methods for analyzing and evaluating present system functioning; identifying problems and causal factors; generating and selecting alternative system structures and procedures; installing new designs; evaluating those designs; and transferring lessons learned to other military settings.

BACKGROUND

Trist coined the term "sociotechnical system" in his study of coal mines in Great Britain (Trist & Bamforth, 1951; Trist et al., 1963). He used it to describe a method of viewing organizations that emphasizes the interrelatedness of social subsystems (the people and their working relationships) and technical subsystems (e.g., tools and knowledge) within the organization. Further, the organization is described as an *open system* because of the interdependent relationship between the organization as a whole and the environment in which it operates. The environment functions as the source of inputs (e.g., resources and raw materials) and as a user of system outputs (e.g., finished products) and usually sets various constraints on system structure and operation.

This conception of organization leads to two important features of STS theory. First, the open system perspective recognizes that organizations must interact with their environments to survive. They must obtain inputs in the form of labor, capital, and raw material, transform these into products or services demanded by the environment, and export them to generate resources to reactivate the cycle of activities. Thus, the organization and its external environment are intimately related.

As environments change, organizations must adapt to maintain their existence over time. Therefore, adaptability of the organizational system becomes an extremely important aspect of its design. A recent example is the emissions and fuel economy requirements imposed by the U.S. government on automobile manufacturers. Adaptation has required massive reallocation of traditional research and development and engineering resources on the part of the auto industry. The high cost of adapting to the new requirements has had many side-effects, such as reducing the amount of change for change's sake (planned obsolescence) and reducing the proliferation of models and drive train options.

Second, the theoretical goal of sociotechnical system design is joint optimization of the social and technical subsystems. Joint optimization is based on the postulation that optimal performance of the entire organizational system will be attained when its social and technical subsystems fit the demands of each other and the unit's environment (Emery & Trist, 1960). The concept of joint optimization contradicts the traditional industrial engineering approach that focuses solely on technical subsystem design, ignoring the social subsystem. Such singular focus can produce unintended negative consequences in the social subsystem, resulting in relatively poor work performance. In contrast, users of STS design methods do not accept technology as a given. They recognize that there are alternative technologies and ways of utilizing them to

accomplish the organization's mission, just as there are alternative ways of organizing people to accomplish a task.

From the perspective of design, joint optimization assumes organizational choice, that is, that several alternative arrangements of people and technology may be used to achieve the same organizational goal. This implies that designers should maximize overall organizational performance by judiciously selecting among available technologies and alternative physical layouts, as well as among alternative sets of roles that people could fill to accomplish required tasks.

Joint optimization can be better understood by examining the social and technical subsystems of organizations. The *social subsystem* of an organization is comprised of the attitudes, beliefs, needs, and expectations of the people who work in the organization and the interpersonal relationships among organization members. These can be examined at both the individual and organizational levels. At the individual level, people bring to the organization their needs, expectations, values, and attitudes. At the organizational level, the members function in a network of roles to accomplish the mission of the organization and maintain its viability over time. As Pasmore, Francis, Haldeman, and Shani (1982) contend, the challenge for STS designers is "identifying the needs that people bring with them to the workplace, and incorporating means of meeting those needs through the design of the technology and work itself." This approach is "the surest way of directing the efforts of organizational members toward organizational goals" (p. 1183).

The *technical subsystem* of an organization consists of the tools, techniques, procedures, skills, and knowledge used by members of the social subsystem to accomplish organizational goals. Choices in technical subsystem design at both the individual and organizational levels affect the social subsystem by shaping the attitudes and behaviors of the individuals required to operate within it. At the individual level, the design of jobs either enhances or hinders workers' learning and skill development through the opportunities made available for variety, challenge, and discretion in the immediate work environment. At the organizational level, superior-subordinate roles are codified in terms of the coordination and decision-making processes required to integrate activities. At the same time these processes allocate opportunities for authority, responsibility, and accountability among organization members.

The intent of joint optimization is to realize the full potential of the organization's resources in accomplishing its mission. This is accomplished in STS design by control of *key variances* during the transformation process. Variance refers to any unprogrammed deviation from standards or procedures. A key variance is one that critically affects the desired outcome. This might be a deviation due to the quality of raw material, the failure of an individual to take action at a critical time, the failure of a machine, or other variations in input or throughput affecting goal accomplishment (Cherns, 1976; Pasmore et al., 1982).

Sociotechnical system design focuses on appropriate placement of organizational boundaries to control key variances. As Miller (1959) has discussed, boundaries can be created individually or in combination along such dimensions as time, territory, or technology. Sociotechnical systems theory prescribes that organizational boundaries be drawn so that the work-related activities and roles of the members within the unit can be carried out in a manner that enables that unit to be self-managing in regard to controlling key variances. When boundaries are drawn inappropriately, other organizational subsystems can interfere with the unit's capacity to regulate itself. For example, maintaining separate organizational units for disassembly and assembly in the pump repair process reduced accountability for and identification with the end product, seriously compromising quality (Feher & Levine, 1984).

The STS design method was previously employed by the Navy Personnel Research and Development Center (NAVPERSRANDCEN) at the shop and organizational levels of the IM system (Feher & Levine, 1984, 1985a, 1985b; Levine & Feher, 1986). Change to semi-autonomous work teams produced a 40 percent increase in productivity in the Pump Shop at SIMA, San Diego (Levine & Feher, 1985a). However, this productivity improvement "stressed" the remainder of the organization involved in the repair of pumps. Ultimately, it required redesign of organization-wide support functions to optimize the entire pump repair system and institutionalize the new design (Levine & Feher, 1985a, 1985b). NAVPERSRANDCEN also has applied this method to analysis of the repair process aboard tenders, with the objective of developing more efficient work systems and ship designs for new tenders (Farkas, 1985). Based on these military applications and the literature on civilian applications, the method was judged highly promising for large military organizations. The following case describes the analysis and redesign of the complex, multilevel San Diego IM system using the STS design method.

THE CASE: THE NAVY INTERMEDIATE MAINTENANCE SYSTEM IN SAN DIEGO

Entry

Surface operational commands based in San Diego were highly dissatisfied with the intermediate-level maintenance system and repeatedly expressed their frustrations via the chain of command to the force commander. In response, COMNAVSURFPAC (Commander, Naval Surface Forces, Pacific) requested that NAVPERSRANDCEN provide recommendations to improve the structure and operation of the San Diego IM system. NAVPERSRANDCEN proposed to use an STS design approach to perform a system analysis, develop recommendations for improvement, and assist in implementing changes in the local IM system.

Several methods were used to gather information about the structure and operation of the IM system in San Diego. These included interviews, observations, and a review of pertinent policies, instructions, and historical records.

A task group was formed to clarify the definition of the IM system mission and to provide a top management sounding board for findings and proposals. It was comprised of senior military managers of key activities in the San Diego IM system, including the commanding officers (COs) of the Readiness Support Group (RSG) and of the shore and afloat IM activities (SIMA and USS CAPE COD [AD-43], respectively). Other participants included the COMNAVSURFPAC science advisor, the Naval Sea Systems Command liaison on the COMNAVSURFPAC staff, and the material officers of Amphibious Group Three and Cruiser Destroyer Group Five.

STS Analysis and Design Process

The STS design process is a method developed to jointly optimize the social and technical subsystems of an organization by a series of steps that help to (1) analyze current system functioning; (2) identify areas that work against joint optimization, including pertinent causal factors; (3) generate and evaluate alternative system structures and procedures that can improve mission performance of the system; and (4) guide installation of the changes and create conditions supportive of their institutionalization. The steps involved in performing STS design are listed in Table 1; they are then briefly described, with illustrations from this project.

Table 1. SOCIOTECHNICAL SYSTEM DESIGN STEPS

	ORIENTATION
1.	Environmental Scan
	TECHNICAL SUBSYSTEM ANALYSIS
2.	Identification of Unit Operations
3.	Identification of Key Process Variances
	SOCIAL SUBSYSTEM ANALYSIS
4.	Macro-Analysis of the Social Subsystem
5.	Micro-Analysis of the Social Subsystem
	SUPPORT SUBSYSTEM ANALYSIS
6.	Analysis of the Tool Upkeep Function
7.	Analysis of Supply, Staff, and User Subsystems
	ENVIRONMENTAL ANALYSIS
8.	Future Scanning
	REDESIGN
9.	Development of Proposals for Change
10.	Implementation of Proposed System Changes

Step 1: Environmental Scan

The initial step in the sociotechnical design process is labeled the environmental scan. The purpose of this step is to identify the main characteristics of the production system by which the inputs are transformed into outputs and to identify the broad environment in which the system functions. The production system can involve any kind of transformation process, including manufacture or repair of a product, information processing, or service to clients. The focus here is to determine problems of integration or coordination and where subsequent analysis should be directed. Environmental scanning is carried out by the system designer in collaboration with key staff from the client organization.

The environmental scan was begun by interviewing VADM G. W. Davis, COMNAVSURFPAC, under whose jurisdiction the IM system for surface ships on the West Coast falls. He had recently assumed his post, bringing to it a greater emphasis on maintenance of the fleet. Although the IM system he oversees covers the entire West Coast, he perceived that the majority of his maintenance problems centered in the San Diego region. Within that region he identified the most important repair activity as the SIMA. His concern with the maintenance process in the San Diego region primarily centered on initiation of the work, rather than the execution or quality of the repairs. His presenting problems were (1) a lack of responsiveness and efficiency on the part of the IM system, particularly in terms of the amount

of effort required to initiate repair actions, and (2) a high level of overhead (non-production personnel) at the repair activity.

The environmental scan was continued by surveying IM system customers in the San Diego region. Using a structured interview, NAVPERSRANDCEN researchers asked customers to identify the strengths and weaknesses of the intermediate maintenance process. Topics raised included the preparation and processing of work requests, the execution of the repairs, and the overall effectiveness of the IM system and its components. The sample consisted of 10 ships representing a cross-section of propulsion systems (steam, gas turbine, and diesel), ship types (amphibious ships, cruisers, destroyers, and frigates), weapons suites (with and without guided missiles), and maintenance data systems (manual versus automated). Forty personnel were interviewed, including COs, XOs, engineer officers, repair officers, and 3M coordinators.

Numerous interviews were also conducted with IM system personnel who interacted with the customers or dealt with the work package at all stages of the repair process. These included RSG type desk officers (TDOs), who screened and brokered the work requests, as well as personnel involved in accepting, planning, coordinating, and performing the repair at SIMA. These interviews helped to identify the key players inside and outside the IM system, the nature of their relationships, and the breakdowns or problems that occurred.

The operation of the Repair Office at SIMA and its staff of ship superintendents were also examined. Finally, SIMA liaison with the customer was examined by attending work definition conferences, availability arrival conferences, and weekly CO conferences.

The environmental scan yielded a consensus that the execution of the actual repairs usually was performed effectively by the existing IM system. However, the preparation leading up to the execution of the repairs required excessive expenditures of effort by various participants. Therefore, it was decided to focus on the generation and processing of the information inputs critical to executing repairs in the IM system in the San Diego region. For the initial focus of the study, SIMA was selected as a representative repair activity, based on its size and importance to the fleet in the region. RSG was also identified as a focus of the study because of its related oversight and decision-making role in the initial processing of the work package.

The next two steps in the STS design method focus on the technical subsystem for processing information inputs to the IM system. Analysis of the technical subsystem involves identification of unit operations and identification of key process variances.

Step 2: Identification of Unit Operations

According to L. Davis (1967),

> Unit operations are. . . the main segments or phases in the series of operations which have to be carried out to convert the materials at the input end of the system into products at the output end. Each unit operation is relatively self-contained and effects an identifiable transformation in the raw material. (p. 1)

By transformation, Davis means a change of state, location, or storage of material, information, or people.

Unit operations were identified by interviews with key personnel involved in processing the paperwork from the customer ships through RSG to SIMA, culminating in a job package in one of SIMA's lead work centers. For instance, the unit operations in preparation for IM system repairs include (a) receipt of the call-down message from the ship listing the job

numbers selected from its Consolidated Ship's Maintenance Plan (CSMP); (b) printing of work requests (WRs) from the CSMP; (c) screening of jobs to repair activities; (d) acceptance of the work by each repair activity; (e) logging in of the WRs; (f) creation of job orders authorizing and planning repairs; (g) ordering of materials; (h) obtaining technical documentation; and (i) forwarding of job orders and associated documentation (the job package) to the lead work centers, with copies to assist work centers.

Step 3: Identification of Key Process Variances

The next step in analysis of the technical subsystem is identification of key process variances in the unit operations and their consequences. Variance is defined as a deviation from some standard or specification. Key variances are those that significantly affect "quantity of production, quality of production, operating costs (e.g., use of utilities, raw material, overtime), or social costs (e.g., the stress, effort, or hazard imposed on personnel)" (Davis, 1967, p. 3). The purpose of this step is to identify unit operations where a deviation from some standard or specification significantly affects desired results.[1] Once the key variances have been identified it is possible to consider alternative control systems to ensure that key variances are held within tolerable limits. For instance, in the IM system the quality of the information submitted by the ship was found to be a key variance; many subsequent steps during the processing of the information and execution of the repair were negatively affected by inaccurate, incomplete, or invalid data.

The control of variances is largely accomplished by organization members performing their roles in the social subsystem. The next two steps in the design process focus on analysis of social subsystem functioning. These steps may be accomplished either through a questionnaire or through interviews with key organization members.

Step 4: Macro-Analysis of the Social Subsystem

A macro-analysis of the social subsystem is conducted to investigate the extent to which the present functioning of the social subsystem complements the workers' capacity to control key variances at their point of origin. This analysis is intended to identify what new organizational relationships or information loops might be required in order to accomplish key variance control.

Macro-analysis of the social subsystem in the IM system revealed that there were numerous points along the path of information flow where members had to make judgments based on ambiguous information or else cause delays in processing the information by sending the work requests back to previous points for clarification or approval. Ideally, information quality would be controlled near its origin (the customer ship). Lacking such control, the social subsystem fostered investment of considerable time and resources in processing the work request in such a way as to compensate for the poor initial quality of the information. This was a largely unsuccessful attempt to control variances. Subsequent control activities resulted in considerable redundant effort as well as extension of the time required for processing the incoming information. For instance, RSG type desk officers were often required to judge whether or not a WR was legitimately the responsibility of the ship's force (hence, invalid for submission to the IM system). If the type desk officer returned the WR to the ship for clarification, there was a substantial delay incurred in processing it, and numerous ship's personnel, from CO to technician, were often required to participate in resolution of the issues involved in the final decision.

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1 Part of this analysis is usually the construction of a variance matrix mapping out the unit operations of a complete transformation process and identifying variances and key variances that may occur in each. A sample variance matrix, generated for a tender repair department (Farkas, 1985), is shown in Appendix A.

Step 5: Micro-Analysis of the Social Subsystem

Next, a micro-analysis of the social subsystem is performed to evaluate the workers' perceptions of their roles. Areas of concern in this analysis include whether or not workers perceive their roles as being responsible ones that foster their commitment and fulfill their psychological needs (e.g., opportunities for variety, challenge, and decision-making). A *properly designed social subsystem* induces positive motivation, a valuable factor in mission performance. In the IM system an often-heard complaint among workers was that they were required to work overtime to compensate for someone else's errors or inadequate work earlier in the repair process. This kind of perception works against building role commitment. While such disincentives were found to occur all too frequently, many workers expressed sincere concern that the fleet's requirements be met by the IM system as efficiently and expeditiously as possible, indicating a positive base on which to build. Effort should be made to channel it constructively.

The next three steps focus on relationships between the work system and support functions and policies. These steps should be carried out by the consultants in collaboration with an action group comprised of representatives from the managerial and supervisory levels of the system under investigation.

Step 6: Analysis of the Tool Upkeep Function

The analysis of the upkeep function for in-house tools and equipment used in the repair process focuses on its relationship to the technical and social subsystems comprising the transformation system under investigation. In this case, the upkeep function of concern was the automated data processing (ADP) equipment that provides management information and production scheduling support to the repair shops. This step does not require detailed investigation of the internal operation of the upkeep function. Rather, the focus is on identifying the extent to which the upkeep function affects the capability of the transformation system to achieve its mission.

This step requires identifying upkeep-related variances, such as production of ship's work packages following call-down, and associated control mechanisms, such as TDO quality checks. The analysts must also evaluate the appropriateness of organizational boundaries that cross functional lines (e.g., splitting equipment maintainers from users). Organizational boundaries are examined to determine whether or not improvements in performance of the transformation system might be achieved through incorporating some upkeep into the functions of the technical subsystem. For example, machine operators might be given some preventive maintenance responsibilities. This step was judged unnecessary since equipment downtime was not cited as a frequently occurring variance in the processing of information in the IM system.

Step 7: Analysis of Supply, Staff, and User Subsystems

In similar fashion, the analysis of supply, staff, and user subsystems focuses on identifying the extent to which these subsystems affect the capability of the transformation system under study to achieve its objectives. Once again, a key focus of these analyses is on the appropriateness of boundaries that cross functional lines. For instance, in the study of pump repair at SIMA, workload planning and scheduling (specialized functions external to the transformation system under investigation) were found to have occasional negative consequences on the transformation system due to a complex link between the time when overtime was reported and the determination of projected labor hours available in the shop.

In the IM system, the SIMA Supply Department and technical library performed critical staff functions related to the success of the repair process. These units were felt to be

functioning adequately to support processing of information through the planning stages of the repair process.

The customer ships, however, were found to be a critical factor in the mission performance of the IM system. Although they are part of the environment of the IM system, they determine the quality of the information input upon which the entire repair process subsequently depends. The quality of this information was found to be a key variance in the transformation process. Some of the reasons for the variability in quality were:

- Generation of WRs by inexperienced junior enlisted personnel who were under conflicting pressures to perform higher priority operational tasks;

- Inadequate training of personnel and inadequate written guidance;

- Inadequate review of proposed WRs by shipboard supervisory and managerial personnel;

- Overlapping scheduling of availabilities, requiring a new call-down prior to completion of the current availability;

- Overlapping repair jurisdictions (e.g., IMAs with Superintendent of Shipbuilding, Conversion, and Repair).

The high variability of the information inputs caused extensive down-stream effects as WRs were processed. The variable quality of information required extensive cross-checking and ship checks, replanning, and even reconsideration of work acceptance decisions. All parties in the repair process suffered substantial waste of resources because of time required for corrective actions. Relationships among parties were also negatively affected--customers perceiving that the IM system was not service-oriented; IM system members questioning the competence of fleet personnel.

Step 8: Future Scanning

Aspects of the environment or the technology relevant to the transformation system under study are likely to change in time. Any information about intended changes should be incorporated in the process of designing a new transformation system. Two areas to be examined are (a) planned alterations in general organization or policies, and (b) development plans for the technical or social subsystems. An example of the latter would be Navy supervisory training for senior enlisted personnel that would affect the social subsystem or ADP equipment acquisition policy that would, in turn, affect the technical subsystem. It was anticipated during this study that all ships in the fleet would eventually acquire automated maintenance data systems. However, comparison of ships with and without SNAP (Ship Non-tactical ADP Program) capability indicated such automation did not reduce the variability in information quality experienced by the IM system.

Step 9: Development of Proposals for Change

A crucial step in the STS design process is generating one or more alternative designs that systematically address the root problems and issues raised in previous steps of the analysis. This step consists of gathering and distilling all of the diagnoses and proposals that have been developed during the process of analysis, considering their viability in terms of the production and social objectives of the organizational system, and integrating them into one or more unified redesign concepts.

This generation and evaluation process should involve key members of the client system (in this case, RSG and SIMA), both for their insights and to foster their feelings of ownership for the ultimate proposal. When consensus is achieved on a new design, it is presented to the sanctioning body (in this case, COMNAVSURFPAC) with sufficient structure and information to form the basis for an organization change program. The redesign concept developed for the San Diego IM system is presented below under "Summary of the System Analysis" and "Issues and Recommendations."

Step 10: Implementation of Proposed System Changes

Once the sanctioning body approves a new design for implementation, the change process begins. Client representatives work in collaboration with the researchers, bringing their joint knowledge of the client system and behavioral science principles to bear on implementing the new structures and procedures required in the new design. This must be done in such a way that affected personnel accept the changes, take ownership of them, and participate in operationalizing them and elaborating the new design concept where necessary.

This collaborative implementation process is a natural outgrowth of the system analysis that precedes it. During the system analysis that documented the transformation process and that led to the development of design alternatives, the researchers acquired the language used in the client system to deal with its internal operations and procedures. Further, they developed collaborative relationships and worked to build mutual understanding and trust. The implementation phase builds on this foundation during the process of working through problems encountered in completing details of the redesign concept. As the redesign is implemented, both parties should be involved in monitoring its operation and resolving difficulties or problems that arise. They should jointly examine solution alternatives from both the operational and behavioral science perspectives prior to taking corrective action.

The change process described above differs from common managerial understanding and practice, because it requires an extended time to install the new design, fine tune it, and stabilize it. It cannot be instantaneously accomplished by issuing a directive. Often adjustments are required both within the subsystem undergoing change and in related subsystems to optimize the new design. These adjustments allow the new design to achieve its full performance potential.

Summary of the System Analysis

Figure 1 is a model showing the flow of paperwork between the customer ship and the repair activity (in this case, SIMA, San Diego) during the preparation for the ship's availability period. The processing of the ship's package of work requests is plotted in relation to the number of days remaining before the beginning of the ship's availability period.

The sequence of events begins at least 50 days before the start of the ship's availability period (A-50), according to the *COMNAVSURFPAC Maintenance Manual* (Instruction 4700.1A [Change 4], 19 February 1981).

Prior to A-50, the ship reviews its current CSMP, listing all maintenance and repair work required, and selects jobs for call-down to RSG at A-50. RSG prints out a work package consisting of automated work requests (AWRs) for the jobs selected by the ship from its CSMP. After screening by RSG, some jobs in the work package are returned to the ship for further information or justification. Depending on the nature of the job, cost constraints, and other factors, the rest of the jobs are brokered to particular repair activities, including SIMA, at about A-48.

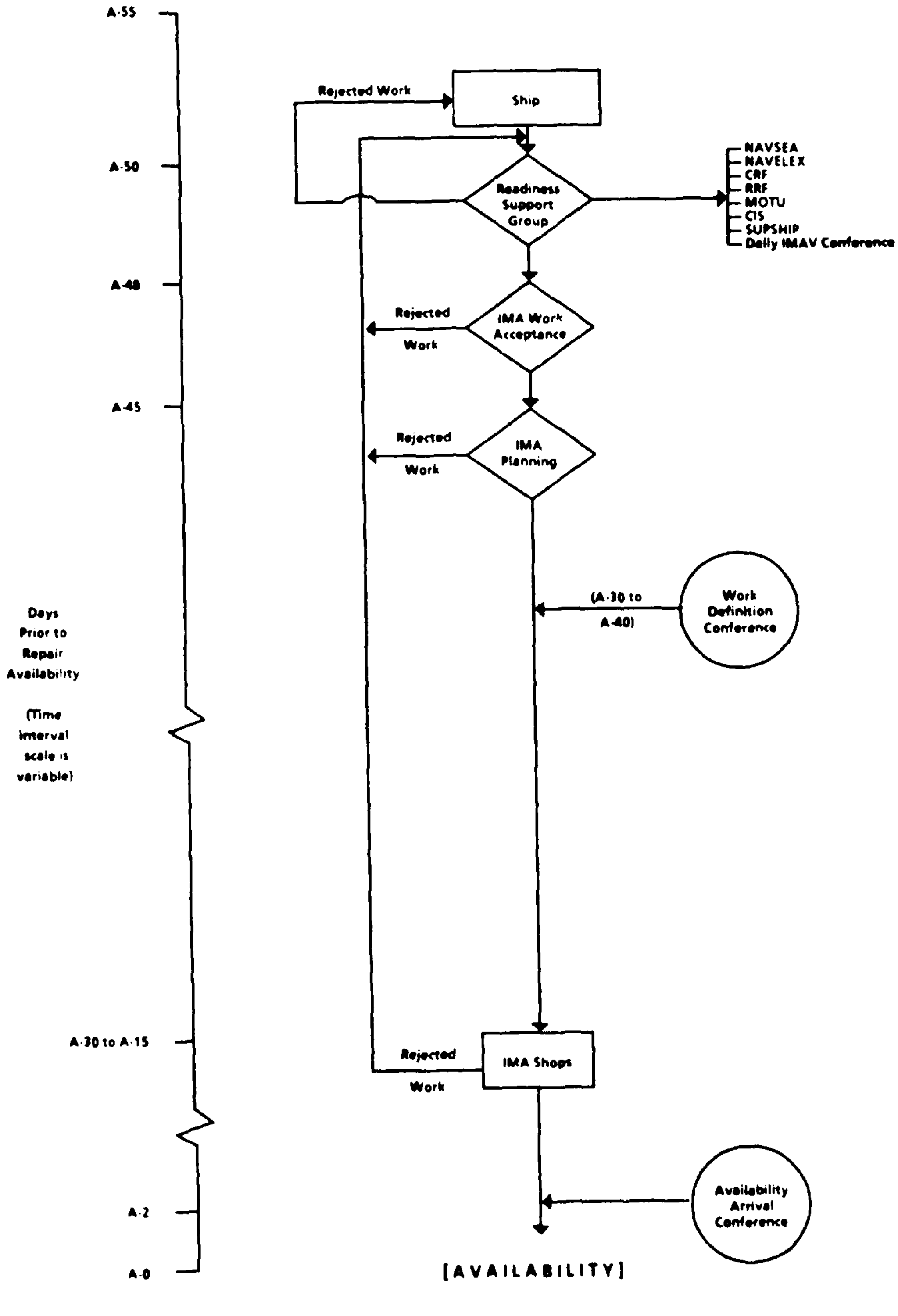

Figure 1. Model of IM system information flow before sociotechnical system redesign.

SIMA work acceptance personnel process the AWRs in the ship's work package and submit them to ADP for entry into the MIS database and inclusion in the Job Order and Material Status (JOMS) reports. Sometimes jobs are rejected due to lack c.̇ capacity or lack of capability to perform the work. If a job is rejected by SIMA, the AWR is sent back to RSG for re-screening or for return to the ship; if the job is accepted, the AWR is forwarded to the Planning Department.

By A-45 the AWRs in the ship's work package are assigned to the appropriate SIMA central planners who develop job orders authorizing the shops to perform the requested work and a job package supporting the repair process. Preparation of the job package for the shop requires that the planner verify the identifying information for the hardware, its location, and the nature of the repair required. Based on this information, the planner initiates a parts order and secures technical documentation, prints, and drawings. These are assembled and forwarded to the shop planners. Although the target for completion of planning is 5 days, a review of actual practice indicated that a majority of jobs were still in planning when RSG conducted the work definition conference with the ship (A-40 to A-30).

Upon completion of planning, a SIMA work package for each job (consisting of a job order, material requirements list, prints and other technical documentation) is provided to the lead work center, with copies of the job order to assist work centers. Between A-5 and A-2, SIMA conducts an availability arrival conference with the ship at which time all jobs in the work package and critical dates are supposed to be reviewed. Although data were not kept, planners reported that, on the average, 30 percent of the jobs in a ship's work package were still in planning at the time of the availability arrival conference and could not be reviewed. To the ship this meant it still had no firm acceptance of the job for execution during that availability period.

Ideally, the shops shipcheck their jobs and arrange for pickup or delivery of the equipment immediately after the beginning of the "avail," work their jobs, and report on their progress to ADP and to the ship superintendent who feeds this information back to the ship. Eventually, the jobs are completed or resolved by cancellation, temporary repair, or some other means.

Issues and Recommendations

The system analysis helped NAVPERSRANDCEN identify three interrelated issues needing immediate attention: (1) the quality of the AWRs in the ship's work packages entering the IM system; (2) the timeliness and finality of work acceptance decisions; and (3) the organization and execution of the planning process. These are discussed below.

Issue 1: Quality of the Work Package

There was widespread concern throughout the surface force over the uneven quality of the CSMPs. While some ships did an excellent job in maintaining their CSMPs, many ships did not. Variability in quality of CSMPs causes problems because the quality of the AWRs can be no better than that of their source. This was recognized as a serious problem by COMNAVSURFPAC and the service providers within the IM system, as well as the customer ships themselves. The resulting AWRs varied along three quality dimensions: validity, accuracy, and completeness.

Validity of Work Package Information. There were several types of invalid work requests. Examples are: request for "R-avail" (restricted availability) work during an "S-avail" (ship-to-shop availability); request for an unauthorized ship alteration; or request for customized

fabrication when a standard stock item was available. Another common invalid work request concerned work that had already been completed but had not been removed from the CSMP.

A more vexing validity problem concerned ship's force work. There was a long-standing lack of agreement in the IM system concerning what constituted organization-level (in this case, ship-level) work. The ships maintained that organization-level work depended on both the complexity of work involved and the current capabilities of the ship's force. For example, under normal conditions a ship might have the capability to do a certain job, but the billets with the necessary skills to perform the work might currently be unfilled. In another case, the ship may have personnel on hand capable of doing the work, but the amount of work to be done exceeds their capacity to do it in time to meet operational requirements. However, in making these determinations, RSG and SIMA historically considered only the nature of the work and not the current capability of the ship, making "exceptions" when subjected to a strong enough appeal from the ship or the operational command.

The IM system's response to a request for what it perceived to be ship's force work had been rejection. Of approximately 28 possible reasons for rejection of work used by SIMA, "ship's force work" had historically been one of the three most frequently cited. In the worst possible case this rejection did not occur until the availability period had begun and the equipment had reached the shop floor. The ship then had to ask RSG to reconsider its concurrence with the rejection decision in an attempt to convince it to find IM support, while critical time was being lost.

Accuracy of Work Package Information. Another serious work package problem was that of inaccurate information. One critical piece of information is the APL (automated parts list) number. It identifies the specific equipment to be repaired, which, in turn, determines the stock numbers of repair parts. If the APL number is in error, incorrect repair parts will be ordered and the job will likely not be completed on time.

Inaccurate APL numbers may be detected during screening at RSG, during work acceptance at the repair activity, during planning, or after the job arrives on the shop floor. Once the error is detected, the AWR is either corrected by the IMA, if possible, or sent back to the ship for correction. It should be noted that any error is costly in terms of time and effort to correct it. Lead time and production time are reduced as well. Generally speaking, the further a job progresses in the IM system before an error is detected, the less likely the system will be able to accomplish the repair during the scheduled availability.

Completeness of Work Package Information. A third problem with the AWRs involved incomplete information. The content of the remarks section was frequently so brief that the repair activity had no useful information from which to estimate what needed to be done and how long it would take. Remarks that said, in effect, "It's broke. Fix it!" did not tell the repair activity whether a relatively minor repair or a complete overhaul was needed to do the job. Lack of this information made it impossible to accurately advance order the necessary parts to perform the repair. The repair activity was not able to make these determinations or initiate required actions until a ship check was performed by the planners or until the item to be repaired arrived in the shop.

The high rate of inaccurate and incomplete AWRs, estimated by SIMA planners to be at least 50 percent, made it necessary for IMA planners to shipcheck almost all jobs. As a result, the processing time in planning was extended on many jobs to the point where the shops could not begin their work at the start of the availability period. This limited the shops' ability to accomplish the work during the availability.

Although verifying the quality of the information on the AWR is probably a required function for accurate planning, logically it should be performed prior to submission of the work package. Placing a SIMA person to perform this function at the earliest possible point in the process should streamline the movement of the repair requests throughout the system due to the increased reliability of the information and the decreased need to shipcheck each job. This person could also advise shipboard personnel regarding the information required by the IM system to successfully complete the ship's repairs in a timely manner.

Recommendation 1A: Maintenance Representative. The position of maintenance representative (MR) should be created out of current RSG and SIMA personnel allowances. Persons in these positions should function as part of the SIMA ship superintendent teams. An MR should be detailed to a ship 1 week before its call-down message is due. Initially, he or she should be selected from among the best planners, ship superintendents, or senior enlisted shop personnel. Such a person should have an appreciation of SIMA capabilities and knowledge about the information requirements at all levels of the repair process.

MRs should be able to do the following tasks:

(1) Verify that all of the jobs the ship intends to call down are on the CSMP. This is most easily accomplished by taking to the ship the most current listing of its CSMP.

(2) Audit all the WRs the ship intends to include in the call-down message to ensure their validity, accuracy, and completeness.

(3) In conjunction with RSG/SIMA work acceptance teams (see Recommendation 2 under Issue 2), determine which jobs do not require ship checks or special procedures and thus can go directly to the lead work center to be planned, bypassing central planning (see Recommendation 3 under Issue 3).

(4) Expedite the ship's work package through the IM system, providing liaison with the RSG/SIMA work acceptance team (see Recommendation 2 under Issue 2), planners, ship superintendents, and the shopmasters, as needed, to ensure correct and timely work acceptance decisions and repairs.

Recommendation 1B: Guidance for Work Request Preparation. COMNAVSURFPAC should issue a new document on the preparation of work requests. This document should be short, concise, and easily understood, with emphasis on the importance of correct, complete, and valid information. Existing documentation (i.e., the 3M Manual) is too long and complex, and it is too general to be useful as a training tool or a reference in a particular case. The distribution aboard ships is also too limited. The new guide should be distributed to every work center aboard surface ships. It should provide explicit instructions on how to determine the correct APL number, and it should specify in some detail, through a variety of illustrations, what constitutes an adequate description of a problem. It should also clarify what constitutes a valid work request. (Such a document was later developed and pretested as a by-product of this project [White, 1986].)

Issue 2: Timeliness and Finality of Work Acceptance Decisions

Both the IM system and ship's force were hampered in their maintenance efforts by the lack of timely and binding work acceptance/rejection decisions. Even though ships submitted work packages 50 days prior to an availability, historically it was not unusual for the availability to start with 20-50 percent of the work package still being reviewed or planned and without binding work acceptance decisions. Therefore, these jobs had not yet been passed to the lead

work center. This delay reduced the probability of job completion by the assigned IMA during the availability. This also decreased the flexibility of RSG to successfully rebroker the work, if necessary. Two interrelated factors contributed to this problem: (1) the multilevel decision-making process and (2) the poor quality of the work package.

Multilevel Decision Process. At the time of the system analysis, the IM system allowed job rejection decisions to be made at several levels within the system, which had a substantial impact on the amount of lead time and processing time available to the repair activity. RSG type desk personnel might reject the work and return the WR to the ship for reasons related to job writeup, job scope, incorrect documentation, or improper work authorization. This level of work package screening occurred 48 days prior to the start of the availability. SIMA work acceptance personnel might reject the work at about A-45 for reasons similar to RSG, but also for lack of shop capacity or capability. Later, SIMA planners might reject the work because actual job scope was grossly inconsistent with the AWR writeup or because work to be performed was not authorized. (In most cases, planners attempted to correct erroneous technical information on the AWR and to continue with the job.) The time frame for a job to progress through SIMA planning normally was 3 weeks (A-42 to A-20), but this was dependent on job complexity and ship availability for the almost mandatory ship checks. Finally, SIMA shop personnel might reject the work because the actual job scope, as determined by shop investigation, exceeded the shop's capability to complete the repair during the availability.

When a work request was rejected, the annotated AWR was returned to RSG via the chain of command. RSG reviewed the AWR and decided whether to return it to the ship, to attempt to place it with another repair activity during the daily intermediate maintenance availability conference, or to submit the job to a local civilian industrial contractor through the Superintendent of Shipbuilding, Conversion, and Repair (SUPSHIP), San Diego. RSG's options were reduced as the work request progressed deeper into the IM system prior to being rejected. The further it went, the less time remained for RSG, upon receiving the rejected AWR, to rebroker the job and get the repair completed on time at a different repair activity. This increased the probability that the work would either be contracted out to the civilian sector, for premium dollars, or be returned to the ship for resubmission at some future availability.

If RSG returned the job to the ship at A-10 or later, the CO had little probability of having the work completed during the availability, even if he appealed the decision and had the work reinstated. He was forced to either defer the work or reprogram work scheduled for the ship's force. For critical work, the CO had to declare the job a CASREP (casualty report, signifying reduced mission capability) to force the system to deal with it on a priority basis. This seriously disrupted other ongoing work.

Impact of Work Package Quality on Work Acceptance Decisions. The quality of the AWR impacted directly on the IM system's capacity to make binding work acceptance decisions. SIMA planning doctrine called for planners to shipcheck nearly every job because of the poor quality of work requests. Both the availability of the ship in port and the workload in the Planning Department affected the timeliness of these ship checks. Because of the number of ship checks required and the inherent delays in performing them, there were at times critical delays in making work acceptance decisions, requisitioning parts, developing repair procedures, scheduling the work, and passing the job package to the work centers.

Recommendation 2: Joint RSG/SIMA Screening. A procedure should be established for work package screening that will enable the IM system to make binding work acceptance decisions 30 days prior to the beginning of the availability (A-30). This can be accomplished

through three related changes:

(1) Using the MR to improve the quality of the work package (see Recommendation 1A);

(2) Forming RSG/SIMA work acceptance teams, based on ship type, to jointly and concurrently perform the brokering and IMA acceptance functions; and

(3) Tasking the MR, in conjunction with the RSG/SIMA work acceptance teams, to determine which work requests must be sent to central planning rather than directly to the shop floor (see Recommendations 1A and 3).

Issue 3: Organization and Execution of the Planning Process

The main function of the Planning Department is to construct a step-by-step procedure for the shops to use when performing the repair work. Its plans deal with two types of work: noncontrolled and controlled. Plans for noncontrolled work involve little more than instructing the repair shops to use existing shop procedures to perform the work. Controlled work packages require many special quality assurance steps--procedures must be carefully planned, reviewed by the Quality Assurance Department, and strictly enforced. This requires additional planning skill and may require that a greater proportion of time be spent in planning than in production, although this can be minimized by development of standard writeups with blanks for variable information.

Although writing job plans should have represented the major portion of the planners' work, many of their tasks were supportive in nature. These included ship checks to verify necessary information on the AWRs (e.g., APL number, the exact location of the equipment to be repaired, accurate and complete description of the work requested) and to determine the existence of any extenuating circumstances not included on the AWR that affected the scope of the work (e.g., removal of hatchways or rebuilding of a pump foundation). In addition, the planner had to order parts to support the repair and had to secure necessary technical documentation.

Though they may be capable operators, senior enlisted personnel usually come into the IMA without any formal training or experience in planning. Further, the task they perform is labor-intensive and has many inherent difficulties. Problems can involve accessibility of the ship for a ship check, finding the designated point of contact, validating/correcting APL numbers, and planning the repair work with complete information unavailable until the hardware is disassembled. These difficulties make planning a time-consuming and imperfect process.

Problems in planning caused subsequent production problems. Although the goal of the Planning Department was to have jobs planned within 5 days, in reality plans often took double or triple that time. When planning carried on to the beginning of the avail, there was inadequate lead time for the shops to obtain parts and assistance to complete the repair work.

Without the opportunity to see the problems inherent in a specific repair request, planners may write job plans that are so inaccurate that they require replanning (officially called revision). Replanning sometimes takes several days. Because many of the availabilities were relatively short (e.g., 3 weeks), such a delay was sometimes fatal to the completion of a repair. Even when jobs did not need to be replanned, the shops still felt that the work packages they received were frequently inaccurate or incomplete, and, therefore, required additional ship checks.

Recommendation 3: Redistribution of SIMA Planning Staff. Central planning should prepare controlled work packages and any additional work packages that require a similar level of expertise, as determined by the MR in conjunction with the RSG/SIMA work acceptance teams (see Recommendation 2). All other planning should be performed by shop- or branch-level planners reassigned from central planning to the shops as permanent shop personnel. They should plan emergent work, revisions, and all noncontrolled work packages that are determined to be routine by the MR and the RSG/SIMA work acceptance teams. Over the long term it is important for central planning to develop programs to prepare and continuously train shop planners and monitor the quality of shop plans.

With shop or branch planners, ship checks would be performed only once for routine work packages. This would be more convenient for the ship and enhance the expertise applied to the ship check. It would also reduce the repair activity's overhead by reducing labor hours expended by staff in doing ship checks, thus freeing repair personnel for production work. Furthermore, moving planners to the shop or branch level would locate them close to production activities where they could get to know shop personnel and procedures and receive feedback on their plans. Finally, this would also enable the remaining central planners to focus on the controlled as well as the more difficult noncontrolled work packages.

Model of the Proposed IM System

As previously described, the analyses revealed three related problem areas in the San Diego IM system: (1) poor quality of incoming information, (2) lack of timeliness and finality in work acceptance decisions, and (3) delays in planning. A number of recommendations were made to overcome these impediments to IM system performance. Figure 2 presents a model of the flow of paperwork in the proposed IM system.

It was proposed that initially no change be made in the time when the ship's work package is required (call-down message at A-50). As efficiencies in work acceptance and planning are realized, the start date could be shifted closer to the beginning of the availability.

The MR position would be filled by someone who, as part of the ship superintendent team, would go aboard the ship at about A-55 (Recommendation 1A). While on board, this individual would advise the ship's force how to ensure the validity, accuracy, and completeness of its work package prior to its submission to the IM system. Written guidance for preparation of work requests would provide the MR and ship personnel with a ready reference (Recommendation 1B) (White, 1986).

Upon receipt of an acceptable work request, the MR would make an initial determination of those jobs that are routine in nature and would not require the involvement of central planning. When the call-down message is submitted at A-50, the package would be forwarded to the newly instituted Readiness Squadron for review. After its review, to be completed by A-48, the work package would be passed to an RSG/SIMA work acceptance team. The MR would assist the team in making both the work acceptance decisions and the final determination of planning responsibility.

Recommendation 3 concerned establishment of joint RSG/SIMA work acceptance teams. These teams, in conjunction with the MR, would screen the work package and accept work for the SIMAs. They would also make a final decision as to which jobs of a routine nature would go directly to the shops for planning by shop planners. Only controlled work packages and other specially designated work would go to central planning prior to the shops. Any work not accepted for SIMAs would be brokered elsewhere by RSG.

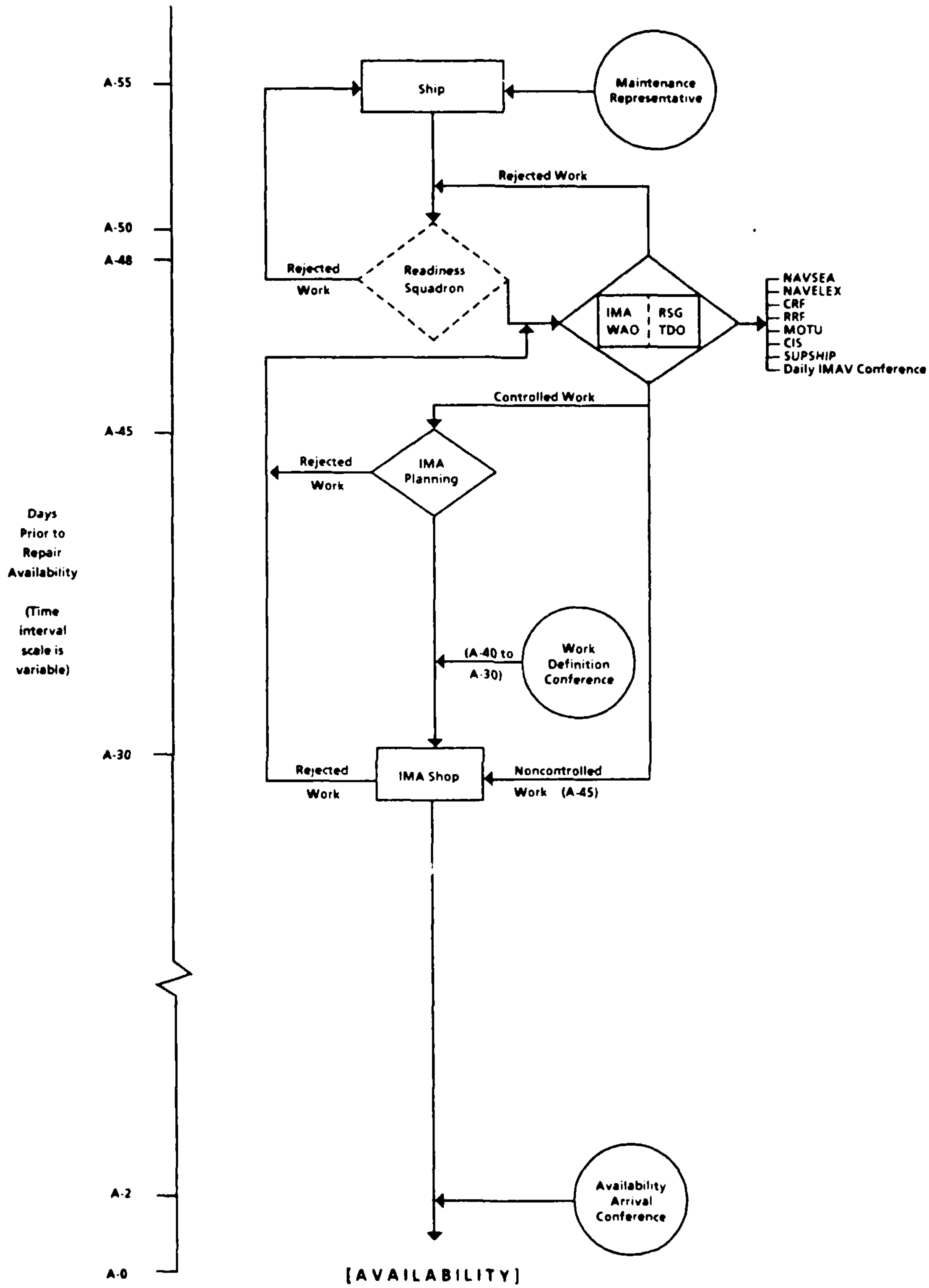

Figure 2. Model of IM system information flow proposed before pilot tests.

Recommendation 4 addressed redistribution of the SIMA planning staff. Only a core group of planners would remain in central planning, tasked to handle controlled work packages and jobs of a complex or unique nature. All other planners would be assigned to the shop or branch level to handle routine work. This would eliminate the need for duplicate ship checks on routine jobs and improve initial planning accuracy by involving shop personnel as resources in the planning process.

Pilot Studies

The results of the analysis of the IM system and the associated recommendations were presented to VADM G. W. Davis (COMNAVSURFPAC) in March 1986. He directed that the recommendations be implemented on a trial basis during the upcoming availabilities of several ships.

The researchers and the SIMA and RSG participants agreed to begin the pilot study by developing and testing a procedure for advance ship visits by the MR (Recommendation 1A). This step was chosen as a starting point based on the rationale that gaining control over the quality of information inputs would reduce downstream perturbations in processing work requests. It would also set the stage for improving decision making (Recommendation 2) and reorganizing planning (Recommendation 3).

An action planning group representing RSG and SIMA worked collaboratively with NAVPERSRANDCEN personnel to develop a more detailed description of the MR position in terms of role, responsibilities, and procedures. Participants from RSG included the CO and type desk officers; participants from SIMA included the CO, the repair officer and his assistants, and the production support officer and his planners.

The action planning group agreed that it would be necessary to develop the MR concept over a series of trials.[2] Performing the trials in sequence allowed modifications of structure and procedures between trials to deal with emergent issues without undue investment of effort in each variation, although evaluation of the design was made somewhat more difficult. Evaluation was aided by selection of a comparison ship that matched each test ship as closely as possible in configuration as well as in terms of the timing and duration of its availability period.

The trials were limited to restricted availabilities (R-avails) of amphibious ships, cruisers, and destroyers. ("Restricted availability" normally involves sizable work packages [100-200 jobs] and a limited time for performing the repairs [2-4 weeks]). The ships represented a cross-section of IM system customers.

The goal of the iterative development process was to create an effective structure and procedures for cleaning up the information inputs to the IM system. As the trials brought to light various issues, the design was refined to encompass and control significant variances.[3]

Pilot Test 1

Design. The design for the initial trial represented a modification of the proposed MR concept. SIMA members of the action group suggested use of an MR team, rather than a single individual. They argued that this would result in a greater breadth of knowledge and expertise

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2 The iterative development process is also consistent with Chern's (1976) principle of "minimal critical specification," which asserts that only minimal behavioral prescriptions should be provided for organization members in order to allow them to elaborate the behavioral requirements as necessary to acheive the goals and standards specified for them.

3 However, not all problems are controllable through design, some problems are due to human error or otherwise not subject to control by design changes.

as well as more personnel time over a shorter period, yielding a more thorough "grooming" of the work package and a higher quality product. It would also likely increase the efficiency of the process for the customer ship. It was, therefore, decided to have an assistant repair officer (ARO) lead an MR team comprised of shopmasters and planners, each representing a functional specialty (hull, machinery, services, or electrical).

The procedures set up for the initial test began about 70 days prior to the beginning of the availability (A-70), when RSG sent a message to the ship explaining the role of the MR team, setting a date for the visit by the MR team, and instructing the ship's force about what to do to prepare for the visit. The ship was instructed to submit a list of jobs to RSG by A-55 to be called down from its CSMP. RSG would print the AWRs drawn from the ship's CSMP and return the package of AWRs (with three carbon copies) to the ship. The ship was instructed to prioritize these jobs, and attach APL numbers and drawings to the AWRs, where required, prior to the visit by the MR team. During the MR team visit the ship's key personnel (chief engineer, repair officer, 3M coordinator, and work center supervisors) were to be available.

The first MR team consisted of the ARO and three shopmasters. The ARO initiated the visit by outlining the team's objectives and the procedure to be followed. He performed an initial screening of AWRs for completeness and clarity, returning inadequate ones for revision. He sorted the remaining AWRs into three sets (hull, machinery, and electrical or services) for ship check by the MR team specialists. Ship checks were performed using a form developed by SIMA to assure thorough review of the job requirements and collection of standardized information.

Upon completion of the ship checks, the team members reviewed their findings with the team leader. Together they decided on a recommended placement of each job for repair (SIMA, Commercial Industrial Services [contract], SUPSHIP, ship's force, NAVELEX, tender, etc.), considering such factors as the capacity of the repair organization to do the work during the availability period. They also constructed a master list of jobs in the work package, ordered by number and noun name of the equipment. Finally, the ARO conducted an exit meeting with the key personnel from the ship to advise them of the recommended disposition of each job and to resolve any outstanding issues. Issues included ship's force work, jobs involving standard stock items, AWRs still needing revision, required inputs to the ship's CSMP, and remaining requirements for drawings. At this point the preprocessing of the ship's work package was complete, and the official call-down was submitted by the ship to RSG. This resulted in a package of AWRs drawn from the CSMP, which was screened by the RSG type desk officer to the appropriate repair activity. When SIMA received its assigned jobs, AWRs were processed through planning.

Lessons Learned. The pilot ship for the first test was a guided missile destroyer with a 1200 psi steam plant undergoing its R-avail with SIMA, San Diego from June 23 to July 18, 1986. The comparison ship was a guided missile cruiser with a 1200 psi steam plant, which had an R-avail from April 28 to May 23, 1986. The ship visit took 3 days.

The visit by the MR team to the pilot ship was delayed by a preceding review by the Board of Inspection and Survey (INSURV), which resulted in the identification of a large number of jobs for the ship to have done. Partly as a result of the INSURV visit, the pilot ship delayed its call-down until the day before the MR team visit. Thus, the printout of the AWRs was not received by the ship from RSG until early on the morning of the visit. This precluded the ship's completion of the preparation of its work package (attaching APL numbers and drawings) prior to arrival of the MR team. Preparations by the ship and processing by the MR team were further complicated by the failure of the RSG to print a usable copy of the work package for the MR team. These procedural problems cost more than half a calendar day of the team's time during the visit.

During the ship visit there was a high level of interaction between MR team members and ship's force personnel, with the result that almost every work request was improved in some substantive way. After completion of the preparatory work, the ship checks and the exit briefing went smoothly.

It was found, however, that a SUPSHIP representative concurrently shipchecked 40 of the same jobs as candidates for an upcoming Selected Restricted Availability. The MR team was required to wait for the decisions by SUPSHIP about which jobs it would take. The residual were then brokered to the IM system. It is noteworthy that some jobs recommended by the MR team to be sent to SUPSHIP for the SRA were not selected by SUPSHIP, and some jobs SIMA would have accepted were taken by SUPSHIP.

Following the visit, the official call-down was passed to RSG for an independent screening. Comparison of the results of the MR team's proposed disposition of the jobs with the RSG screening decision showed a high degree of agreement. However, the MR team was willing to accept some jobs for SIMA that would have been rejected by RSG as requiring a greater capacity than that available at SIMA, San Diego. Whereas the normal rate of rejection of work requests by RSG for steam-driven cruisers and destroyers averaged 41 percent, only 12 percent of the pilot ship's package was rejected; this was better than a two-thirds reduction in the rejection rate. The resulting SIMA work package consisted of 145 jobs, after the jobs taken by SUPSHIP were eliminated. Data obtained following completion of the availability indicated that an additional 4 percent of the work package was ultimately cancelled by SIMA. This rate of cancellation was about the same as that for the comparison ship, indicating that the rate did not worsen due to early firm commitment to accept work requested by the ship.

The RSG screening and SIMA work acceptance process required 8 days. Once in planning, many of the jobs were re-shipchecked. This was reportedly done because the planners either lacked confidence in the information provided by the shopmasters on the MR team or they needed some information omitted from the ship check forms. Repeat ship checks may have been required because the shopmasters were not easily available for questions.

Based on the first pilot test of the MR team concept, it was concluded that:

- o A milestone date should be set in advance of the ship visit at which time the ship should call down its preliminary work package, allowing time for the ship to complete its preparation of the package for the MR team visit;

- o The request for call-down of the preliminary work package should be treated by RSG as a normal call-down, with expeditious printing and multi-copy printout;

- o A high proportion of AWRs from the CSMP required clarification or revision before they could be used by screening, work acceptance, and planning personnel in the IM system;

- o Time and effort required by IM personnel later in the repair process were considerably reduced because of resolution of AWR problems by face-to-face discussion at the point of initial input to the IM system;

- o Better coordination is needed between RSG and COMNAVSURFPAC Maintenance and Engineering (N4) to prevent redundant efforts (e.g., ship checks of same jobs by SUPSHIP and the RSG-designated repair activity);

- o MR team members should be selected from the planners rather than the shopmasters. Their availability during the planning process and shared perspective with other planners should facilitate the planning process following the ship visit by reducing the number of repeat ship checks required;

- o Work acceptance for SIMA should be performed by the ARO, eliminating the need for RSG to screen and assign work and for the SIMA work acceptance officer to accept it.

- o Work accepted by the SIMA ARO should be hand-carried by the team members directly to the Planning Department at the end of the ship visit, with an information copy to RSG, thus maximizing lead time for parts ordering;

- o Work not accepted by the SIMA ARO should be brokered in the traditional manner by RSG;

Pilot Test 2

Design. The procedure and the team composition were modified to incorporate the lessons learned during the first pilot test. A preliminary call-down date was specified in the RSG message to the ship. The AWRs were printed on standard forms and received by the ship sufficiently in advance to complete its preparation of the package prior to the MR team visit. The team was made up of planners, led by the ARO for amphibious ships. The ARO was authorized to accept work for SIMA, with notification of RSG. This procedural change enabled the team to save time by delivering the AWRs for most of the accepted jobs directly to the SIMA Planning Department; only a small number of jobs were expected to require delay of planning action to accommodate additions or revisions to the CSMP. Jobs not accepted by the ARO for SIMA were routed to RSG with an MR team recommendation for assignment.

Lessons Learned. The pilot ship for the second test was an amphibious landing ship with a diesel engineering plant. Its R-avail with SIMA, San Diego began July 28 and ended October 10, 1986; the comparison ship was an amphibious transport ship with steam engineering plant whose R-avail was scheduled from July 21 to September 26, 1986.

The composition of the MR team was adjusted by the ARO to reflect the distribution of work in the work package resulting from the ship's initial call-down from its CSMP--in this case, a second hull planner was added. The preliminary call-down date allowed the ship to complete its preparation of the work package prior to the visit of the MR team. This smoothed the review of the work package and ship checks by the MR team. The total time required for the ship visit was only 2 days. However, some ship checks were duplicated by the port engineer who was preparing the ship for an upcoming Phased Maintenance Availability (regularly scheduled maintenance period between overhauls).

Subsequent to the ship visit, RSG expressed concern over its loss of control over brokering of the work if parts of the work package were directly accepted for SIMA by the MR team.

It was concluded from this second pilot test that:

- o RSG should be involved in the advance ship visit to (1) coordinate the allocation of jobs between COMNAVSURFPAC Maintenance and Engineering (N4) and itself; (2) decide the assignment of jobs to its IM

activities, considering the brokering recommendations of the MR team; and (3) acquire experience in order to spread the MR team concept and ship visit process to the afloat IMAs;

- Team composition should be fluid in terms of the number and type of planners included, and, where necessary, assistance from other Planning Department resources should be used;

- The visit by the MR team was highly beneficial in improving the accuracy and completeness of the work package information for the IM system;

- The MR team leader was fully capable of performing the function of the SIMA work acceptance officer;

- Time was saved in the brokering and work acceptance phases of jobs bound for SIMA, because the AWRs were taken directly from the ship to the SIMA planners;

- The traditional work definition conference between SIMA and the ship could be replaced by the MR team exit meeting;

- Use of planners on the MR team had the expected effect of reducing the number of redundant ship checks during the subsequent planning process;

- Because the planning process was completed more efficiently (as little as half a day required to plan all the electrical jobs), job packages arrived at the shops with much more lead time;

- The total labor hour investment by the MR team in performing the advance ship visit was cost-effective compared with the traditional planning procedure involving numerous independent ship checks;

Pilot Test 3

Design. The general procedure established in the second pilot test was followed in the third, with several significant changes. The message to the ship notifying it of the MR team visit was refined to clarify the ship's understanding of the MR team's role. RSG was given a leadership role in the MR team and responsibility as the ship's official point of contact until the beginning of the avail. The MR team's exit briefing served as the ship's work definition conference, eliminating the need for the later meeting.

Lessons Learned. The pilot ship for the third test was an amphibious transport ship with a steam engineering plant. Its R-avail with SIMA, San Diego was from September 15 through October 3, 1986. The comparison ship was the same ship used in the second pilot test. Its R-avail was from July 21 through September 26, 1986. This ship visit was completed in 2 days.

The results of the third pilot test led to the following conclusions:

- RSG's participation in the ship visit enabled it to efficiently clarify any issues involved in screening the ship's work package and to resolve any differences in opinion between SIMA and the ship's representatives;

- o RSG's leadership role in the MR team eliminated the need to sequentially "rescreen" jobs accepted by SIMA, since the screening process now involved all parties. This change effectively put into practice Recommendation 2 concerning joint screening. This improved both the timeliness and the finality of work assignment and work acceptance decisions;

- o With the bulk of the job assignments resolved during the ship visit by brokering them to SIMA, RSG was able to concentrate further screening effort on brokering the remainder of the ship's package that was beyond SIMA's capabilities, thus expediting that process;

- o Screening and work acceptance by the MR team enabled direct delivery of jobs to SIMA central planning or shop planning, allowing immediate initiation of the planning process;

- o The exit briefing clarified for the ship the disposition of the majority of its work package. It also eliminated the need for the later work definition conference.

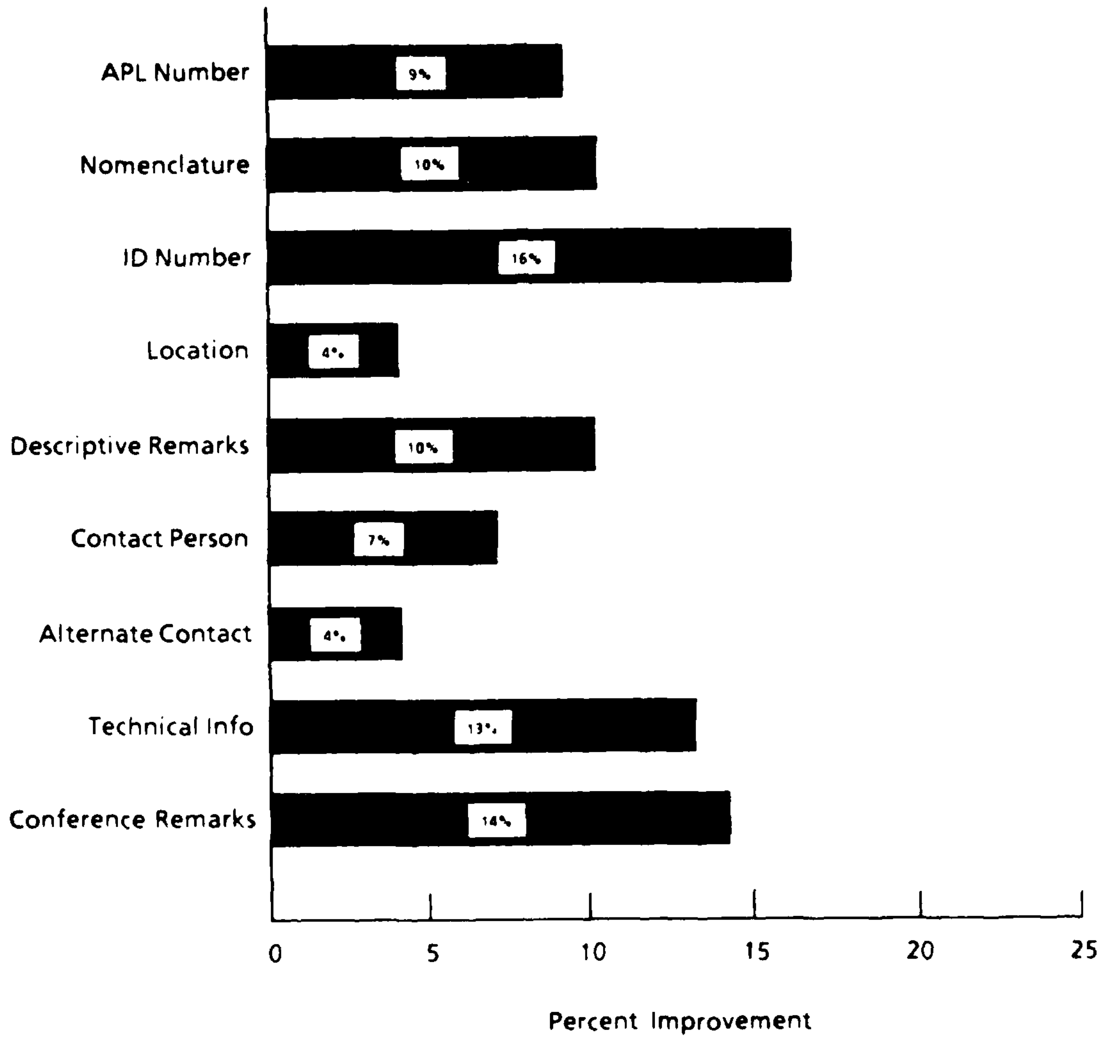
Overall Pilot Test Results

Results were obtained on three measures reflecting the quality of work requests: (1) the accuracy and completeness of work request information (rated by the planners), (2) the incidence of additional ship visits to verify data during the planning process, and (3) the length of time for processing of work requests through planning.

The data consistently support the conclusion that the advance ship visits by the MR team produces improvements in the quality of work requests. Data from the three SIMA trials show that the quality of information input to the repair system notably improved for the pilot ships as contrasted with the comparison ships (Figure 3). In addition, work requests requiring ship checks during planning were reduced from 37 percent to 3 percent. Also, calendar time required for planning was reduced by 27 percent, from an average of 6.7 days for work requests from comparison ships to 4.9 days for those from pilot ships. These differences were statistically reliable and significant. (These results are presented in more detail in Appendix B.)

The quantitative findings were strongly corroborated during observation of the interactions of the ship's personnel and the MR team during the ship visits. Numerous corrections, additions, clarifications, and justifications occurred during review of the work requests. The net result of the interactions was that the MR team had a clearer picture of the ship's maintenance requirements, more confidence in the validity of the information, and stronger commitment to accomplishment of the repairs.

The flow of paperwork that evolved during the trials is shown schematically in Figure 4. Briefly, at about A-70, the ship was notified by RSG to submit its preliminary call-down at approximately A-54. Upon receipt of the call-down message, RSG printed the work package by extracting the jobs specified from the ship's CSMP stored in the Waterfront Maintenance Management System databank. One copy was provided to the IMA and the other copies were given to the ship. RSG and the IMA reviewed the number and distribution of jobs in the work package while the ship completed the attachments required in preparation for the visit of the MR team at about A-51.



Note. All ratings were significant at $p < .05$, except those for APL Number and Alternate Contact, which were significant at $p < .10$.

Figure 3. Improvement of average quality of work requests of pilot ships (N = 251) over that of comparison ships (N = 142).

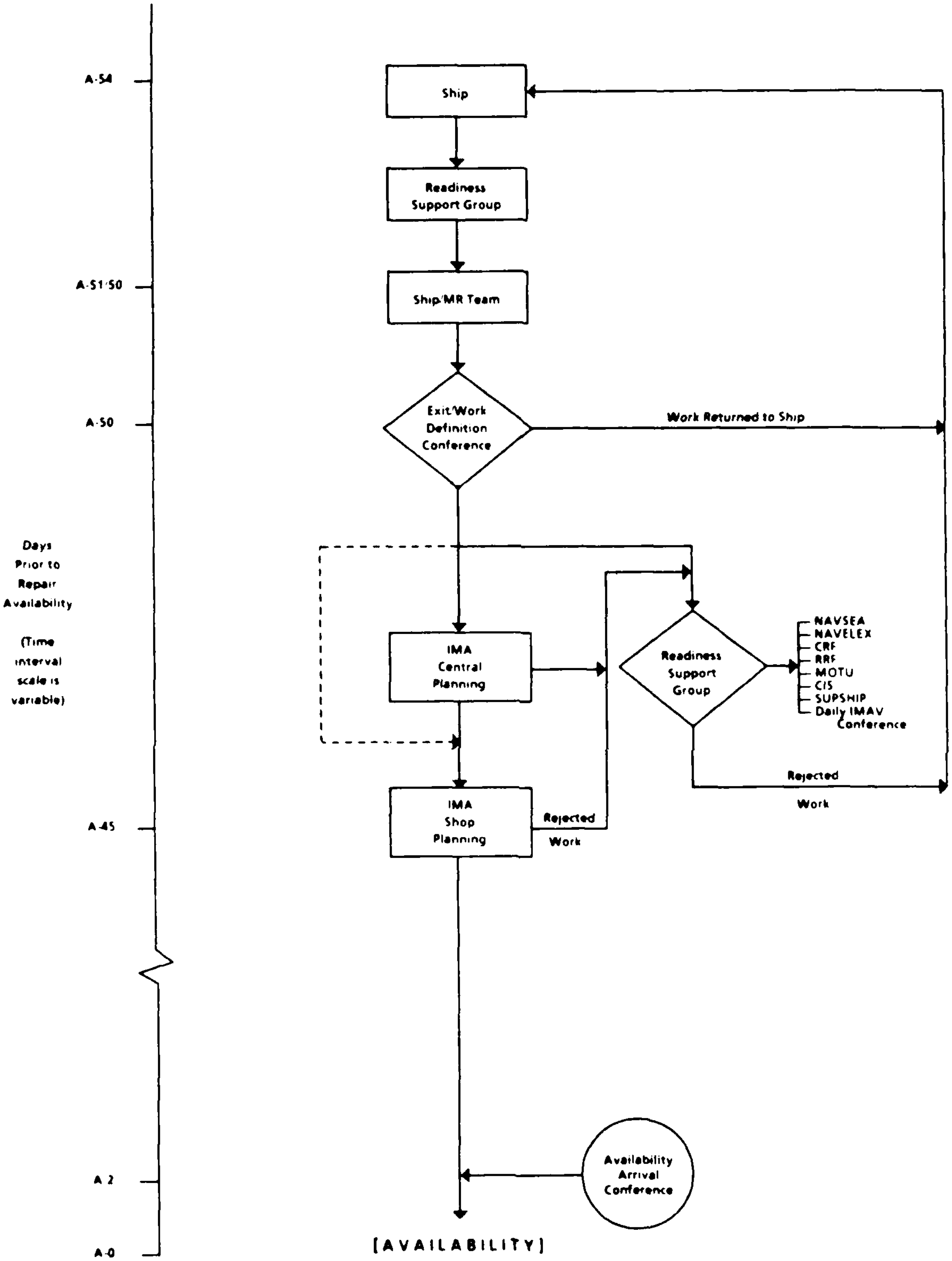


Figure 4. Model of IM system information flow that evolved during pilot testing.

During a 2-day ship visit the package was groomed, ship checks were performed, and the work was brokered to the IMA, alternative public or commercial repair facilities, or returned to the ship for ship execution or resubmission at a later avail. The visit concluded with an exit/work definition conference at A-50 at which time all parties reviewed the disposition of the work package.

The IMA personnel delivered the work requests they had been assigned to their activity. These were logged into the MIS and either processed by central planning or passed directly to shop planners (in the case of routine jobs). By about A-45 the shop planners received most of the jobs. They could then order additional parts that the shop personnel judged to be required.

At about A-2 the IMA held an availability arrival conference with the ship's personnel to review the status of the work package and the ship's critical events related to the required completion date for each job. (Throughout the processing of information and repair of the component there remains a small possibility that unanticipated problems may require that a job be rejected or deferred. However, if it is possible, the completion date is extended so that the repair can be completed.)

System-wide Implementation

Based on these pilot test results, in October 1986 COMNAVSURFPAC directed implementation of the MR team concept throughout the San Diego IM system. However, since the IM system includes tenders as well as shore IMAs, the concept was tested on a tender to examine its suitability there. The procedure established during the pilot tests was transferred relatively intact.

The pilot ship was a 1200 psi steam-powered frigate, scheduled for an availability with a San Diego-based tender. The tender was drastically undermanned (by about 30%) in its repair department, and this deficiency was reflected in its planning office, which had only four people assigned to it (less than half of the full complement). Thus, the ship visit required that the planning office be completely closed down temporarily.

Based on this initial test in the afloat IMA setting, it was concluded that:

- o Technically, RSG does not have control over the tender and its resources; however, the ability of the MR team members from RSG and from the tender to work together in a spirit of cooperation can overcome any potential problems;

- o As in pilot tests with shore repair activities, tender repair departments could benefit from improved quality of information submitted in a ship's WRs;

- o Intensive review of the whole work package at initial submission was beneficial in terms of maximizing planning efficiency and lead time for procurement of materials;

- o Manpower constraints in the tender planning office must be considered by the tender command and RSG so that planning services do not have to be interrupted during an MR team visit. This may require fewer persons on the MR team or temporary detailing of personnel from the SIMA Planning Department to the tender.

DISCUSSION

This case demonstrates that the STS design method is useful in military organizational settings and overcomes the shortcomings of traditional productivity improvement approaches. Application of the STS design method fosters systematic and comprehensive analysis of system functioning to identify problems. The capability to deal with problems across system levels is often important in diagnosing the nature and root causes of performance problems in complex organizational systems.

Analysis of the San Diego IM system revealed some internal productivity and efficiency problems to be symptomatic of factors outside the IM system boundary related to critical information inputs. Over time, the repair organization had made various unsuccessful attempts to bring about improvement in the quality of information received concerning needed repairs. It had also changed its structure (e.g., inflated manning in central planning) and procedures (instituted extensive ship checks) to cope with the variable quality of information inputs.

Ultimately, the quality of information inputs to the repair process had pervasive effects on both the repair system's productivity and efficiency and the fleet's level of readiness and satisfaction (particularly in regard to the effort required to obtain repairs and the unpredictability of the outcomes). These factors, along with an anticipated increase in the IM system workload, created increasing pressure to improve delivery of IM to the fleet.

It was clear that the quality of information inputs to the IM system was determined at the point of origin of the work requests, that is, the sailor in the work center of the ship requesting the repair. Previous attempts to alter the sailor's motivation, knowledge, and/or skill in preparing work requests by typical Navy actions (e.g., issuing instructions, imposing review by higher authorities, or rejecting work requests) had proven unsuccessful. Eliminating the cause of the problem thus required redesign that would change the behavior of personnel who were beyond the boundaries of the repair system. Although environmental factors are usually taken as givens (i.e., unchangeable), this study demonstrated that redesign of structures and procedures at the system boundary can bring environmental factors under system control. This, in effect, enlarges the system boundary.

In essence, the problem was a joint one involving both the customer ships and the repair system, neither of which was capable of independently correcting it. However, members of both systems, cooperatively pooling their knowledge of the equipment repair requirement and the repair system's information needs, were able to produce information of the best possible quality. This collaborative effort required that the existing boundary between the repair system and its environment be relocated by extending the repair system's control over customer system functioning (Feher, Riedel, Levine, Farkas, & White, 1987). This need to intervene at the system-environment boundary was apparent from the history of futile attempts to adapt to the poor quality of information inputs by, for example, instituting a policy of 100 percent ship checks during planning.

The first step in bringing about change was to create an alternative system design (i.e., structures and procedures) that could alter the existing relationships and provide a vehicle by which the participants could reach their mutual goal (usable work requests). A Maintenance Representative position was proposed, to be filled by a person who could deliver to the customer ship the required knowledge from the repair system to help guide the ship's preparation of the repair package. This could take the form of feedback to the ship regarding its proposed information inputs to the repair system and prospects for particular repairs. This initial concept was sanctioned for pilot test and further developed through the collaborative efforts of researchers and system members. It finally took the form of an MR team made up of representatives from key areas of planning and repair.

Results of the pilot studies showed that relocating the organization-environment boundary to give the IM system proactive control over the quality of information inputs improved system performance. Full system-wide use of MR teams should further improve efficiency (e.g., reduce overhead) and, possibly, reduce the lead time required for call-down of work packages by customer ships. Customers should also value highly the gains made with regard to coordination and the timeliness and finality of screening/work acceptance decisions.

An issue raised during the pilot test concerned the source and level of expertise required to staff the MR teams. This was resolved by drawing from the pool of experts available in the SIMA Planning Department and Repair Office. This action represents a very efficient reallocation of resources, since investment of the experts' time at the initial stage in the repair process paid rich dividends in efficiency and coordination during later planning and repair. It was decided to allow the size of the team to remain fluid, based on the type of ship and the size of the work package it called down.

It should be noted that authority as well as expertise is a critical factor in the makeup of the MR team. In this case, SIMA alone did not have the authority to make work acceptance decisions in direct response to ship requests, because this in effect bypassed the brokering function exercised by RSG. Therefore, the team makeup is inter-organizational (RSG, IMA) as well as inter-trade (hull, electrical, services, and machinery).

Joint processing and decision making regarding each of the WRs in the ship's work package allow the paperwork to flow directly from the ship to the repair activity. This procedure requires less calendar time than that required by the traditional system where information flows sequentially from one level to another. It also nearly eliminates the return loops, which greatly extend the processing time, because all parties are present to resolve problem cases immediately.

More time can be saved by separating jobs according to planning expertise required (as suggested in Recommendation 2). Shop planners could handle routine jobs and central planners could process controlled work and highly complex jobs. The largest portion of work would likely fall in the routine category, where several days of lead time would be gained by the shop if it received the work directly from the MR team.

Relocating the organization-environment boundary has an impact on internal system structure and operation. With the MR teams, the information flow and decision-making processes leading up to the availability were streamlined. All key personnel providing authority, coordination, repair expertise, and operational experience were brought together on site to elicit and record the best available information and decide on the action appropriate to each job. This created the best possible condition for generating high quality decisions regarding the disposition of each work request. The elaborate procedures and structures created in the past by the IM system to deal with incomplete and inaccurate information may be simplified as the quality of information improves. A primary target should be reductions in overhead within RSG and SIMA by eliminating duplicative functions involved in screening, work acceptance, and planning.

With improved efficiency in processing the work package information, it is also possible that ships could submit their work packages closer to the beginning of the availability period without compromising the lead time required by the IM system for parts ordering. This would allow more accurate determination of the ship's maintenance requirements at the time of the availability, reducing emergent work. This, in turn, would result in fewer disruptions of the production process and reduce inefficiencies during the repair process. The timing of the call-down should consider the needs of both customer and repair system, providing enough lead time for the repair system to obtain parts for critical repairs while minimizing the lead time for the

ship so that it can submit a complete and accurate work package. This balance between opposing needs hinges on a mutually agreed definition by the customer and the IM system of what constitutes time-critical jobs.

This case demonstrates the power of the STS design method in pinpointing root causes of problems of complex systems, generating and refining alternative system designs to eliminate the problems, installing and evaluating the new design, and institutionalizing it. When the results of this study are combined with those of an earlier one undertaken by NAVPERSRANDCEN at SIMA, San Diego concerned with redesign at the shop and organization level (Levine & Feher, 1985b), it becomes clear that the method is applicable at all system levels. Because the STS design method can deal with relationships across system levels, it is capable of considering the impacts of redesign throughout the organizational system. This is important for increasing acceptance of changes by employees and management, leading to maximum system performance after implementation.

From a managerial perspective, the case demonstrates that system productivity and efficiency may be strongly related to factors external to the system. Compensations by the system to accommodate these external factors suboptimize overall performance by diverting resources away from production, forcing the system to accept the opportunity costs. Tracing the causes of system problems and attacking them directly, even though they are beyond the system boundary, can produce a dramatic improvement in system performance.

The STS design method is a highly "robust" one that is suitable for use in military settings. It is a powerful tool for accomplishing the fundamental restructuring required for long-lasting improvements in productivity and efficiency. The method produces synergistic results by providing a vehicle for collaborative activity by clients and researchers. Working together they capitalize on the expertise of each other--the clients bringing to the relationship technical know-how and a knowledge of internal procedures, and the researchers bringing to it a knowledge of behavioral science method and theory.

CONCLUSIONS AND RECOMMENDATIONS

1. System-wide implementation of MR teams within the San Diego IM system has produced significant improvements in system efficiency and performance. This process of system performance enhancement should be continued by reassigning some staff personnel at SIMA and RSG to production functions, including the newly created shop planner positions. The Planning Department should provide ongoing training of shop planners, who should carry the bulk of the planning load. Also, the timing of the ship's call-down should be reexamined with the goal of shortening the advance period to the minimum workable within this more efficient process.

2. The STS design method is an effective tool for organization analysis within military settings because it can highlight root causes of system performance problems. Having identified causes, the method is useful then for developing and implementing solutions in the form of new organizational structures and procedures that improve overall mission performance. Alternatively, the STS analysis can be used as the basis for selecting an appropriate change technology to meet a particular need of an organization, such as gain-sharing or training system design. Because these solutions address the causes of fundamental problems, improvements in mission performance should endure. Therefore, the STS design approach should be a method of choice where system-wide productivity improvements are sought.

3. Through its emphasis on control of key variances (unplanned deviations) in system transformation processes, the STS design method aids system managers in judicious investment of their limited resources. The method also helps managers target areas for redesign by

identifying problems that have widespread effects on outcomes. This is an efficient way to raise overall system performance.

4. The comprehensive and systematic nature of the STS design approach provides a way to deal with the structural and operational interdependencies within complex, multilevel systems. This method should be used to analyze and redesign organizations where complex interrelationships are involved in determining system performance.

5. While the method is generalizable to a wide variety of organizations, the outcomes should be tailored to the needs and circumstances of specific systems. Organizations should use the method to develop their own unique redesigns, rather than to transfer solutions developed for other organizational situations.

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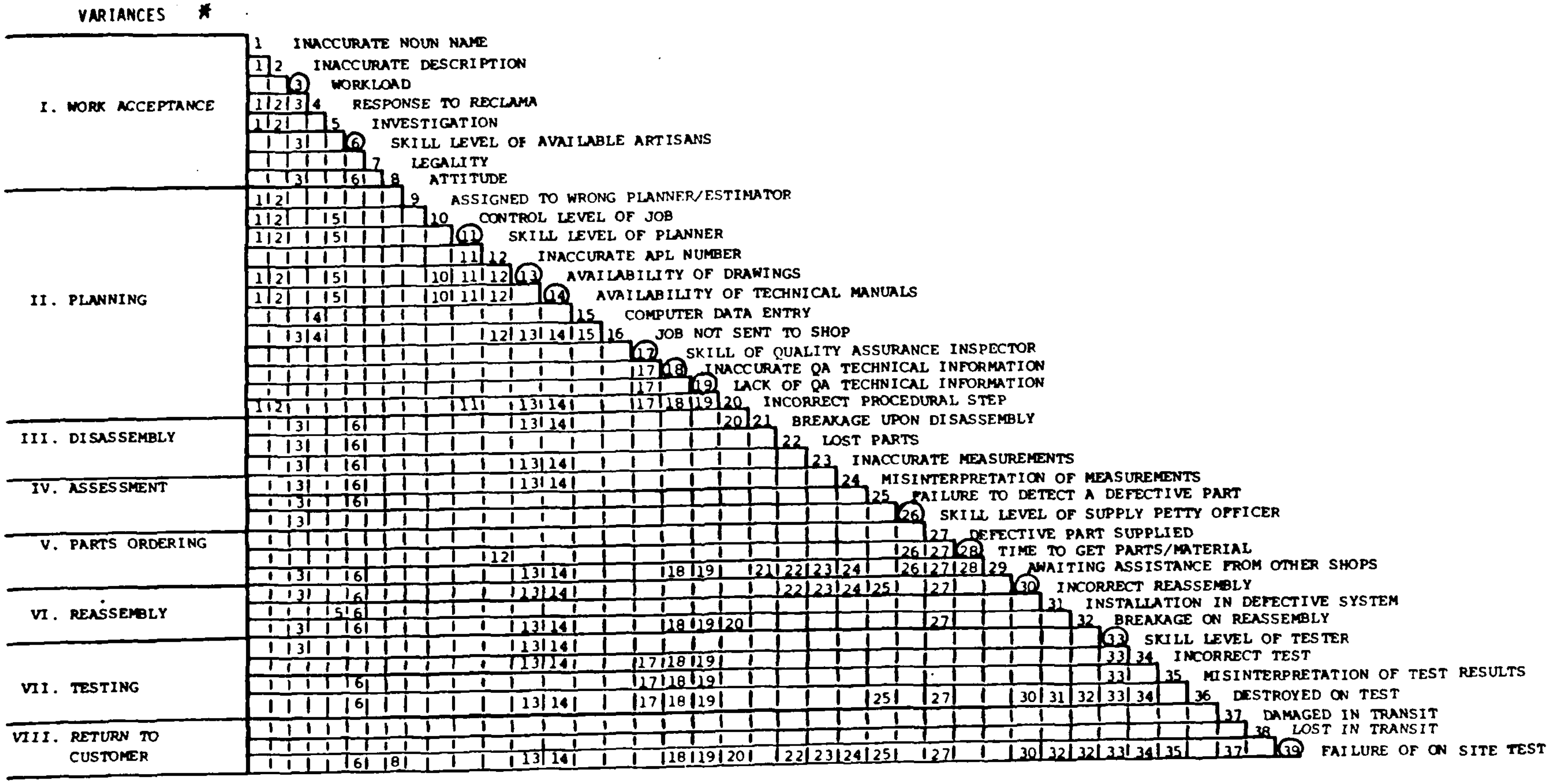
APPENDIX A: SAMPLE VARIANCE MATRIX



* Many events or "variances" can affect how well the IMA repairs a component. Each row lists a different variance, e.g., the sixth concerns "skill level of available artisans," and is cited in the column across from variances 8, 21-25, 29-32, 35, 36, and 39, demonstrating the impact that skill level of artisans can have on these other events or conditions. Some variances have more impact on the repair of a component than others; these have been circled. They are designated key variances.

Figure A-1. Generalized variance matrix for the repair process of an IMA.

APPENDIX B: ANALYSIS OF PILOT TEST DATA

ANALYSIS OF PILOT TEST DATA

Data on the accuracy and completeness of the work requests were collected from planners on a 13-item scale (Table 1). Coefficient Alpha (Cronbach, 1951), a measure of internal consistency, yielded a standardized score of 0.60 for the 13-item scale. This is an acceptable level and indicates that these items may be combined to form a single scale (Nunnaly, 1967). A t-test of the aggregate scale scores contrasting pilot and comparison ships was performed, followed by t-tests for each of the 13 component items.

The test of the aggregate work request evaluation scale shows that the pilot ships had significantly more accurate and complete work requests overall ($p < .001$, Table 1). Furthermore, the evaluations of the work requests by the planners showed that the pilot ships significantly out-performed the comparison ships on 9 of the 13 critical information dimensions (seven at $p < .05$; two at $p < .10$).

Data on additional ship checks and planning time were collected from organizational records. T-tests were performed to compare both the propensity for additional ship checks and the number of days in planning.

Table 1 shows that the propensity to recheck work onboard ship during planning was significantly lower for the pilot ships than for comparison ships ($p < .001$). Furthermore, the work requests for pilot ships took significantly less calendar time (27% savings) in the planning process than those for the comparison ships ($p < .05$).

Table B-1

Significance Tests of Differences Between Work Requests of Pilot and Comparison Ships

Measure	Pilot Ships Mean[a]	Comparison Ships Mean[b]	p value
Work Request Accuracy and Completeness[c]			
APL Number	.31	.40	$p = .058$
Nomenclature	.03	.13	$p < .001$
ID Number	.16	.32	$p < .001$
Equipment ID	.09	.07	$p < .550$
Location	.03	.07	$p = .047$
Ship Alteration Required	.04	.03	$p < .550$
Descriptive Remarks	.04	.14	$p < .001$
Contact Person	.05	.12	$p = .009$
Rate of Contact	.23	.17	$p = .147$
Alternate Contact	.02	.06	$p = .053$
Technical Information	.26	.39	$p = .010$
Conference Remarks	.02	.16	$p < .001$
Drawings	.11	.12	$p = .873$
Aggregate Scale[d]	-.08	.14	$p < .001$
Planner Activity			
Perform Ship Check[e]	.03	.37	$p < .001$
Planning Time			
Days in Planning	4.90	6.70	$p = .048$

a $N_{\text{work requests}} = 251$

b $N_{\text{work requests}} = 142$

c Proportion of work requests found in error during planning.

d T-test based on z-score transformations.

e Proportion of work requests that required ship check during planning.

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